FARES IN EMME/2 REVISITED

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1. Background

The public transport modeller new to Emme/2 may be surprised to find a complete absence of the word 'fare' in the manual index. In the UK at least this absence causes problems as a common question from those people interested in Emme/2 for public transport work is 'how does Emme/2 model fares?'.

In UK public transport, fares have always been an important issue in modelling because of the general lack of integrated fare systems, particularly on bus-based systems where the norm in most places is still the payment of a new fare each time a vehicle is boarded. Although there was a move towards more integrated fares in the 1970s and 1980s, deregulation and privatisation have tended to make the existing fragmented situation worse. In particular the operation of rail services by different rail operating companies has recently resulted in different fares on some competing services and this trend appears likely to continue. A further practical issue when it comes to promoting Emme/2 is that competing software tends to model fares more explicitly. This does not necessarily mean that the results are in any way better or more realistic than those obtained by Emme/2 but it does make it considerably easier to answer the above question!

2. Purpose of this Paper

The main purpose of this paper is to review this issue within a UK context and hopefully promote discussion and generate some ideas from other users. It is written from a consultancy background where there is a constant need to very quickly train new users in how to use the software and where the above question soon arises. In addition our clients often want answers yesterday and are not too interested in the 'yes but' type of answers it is often necessary to give. Unfortunately the constant deadlines of consultancy life do not lend themselves to implementing complex 'workarounds' or give time for detailed theorising about what is and what isn't possible so the lack of explicit fares modelling is often perceived to be a real handicap.

3. Why Model Fares ?

There are a number of reasons for fares to be included in a public transport model:

- because fares affect the route chosen by the passenger through the network;
- because fares affect the choice between services on the same route;
- as an input into a matrix based mode choice model; and
- to calculate revenues.

The first two are related in that they are both concerned with the basic assignment process and the calculation of the routes through the network. The other two are concerned with using outputs from the assignment process.

Usually fares are seen as a component of generalised cost which affects routeing in the same way as the other components of journey time. Most models effectively treat fares in this way and the problem is how to calculate the fare that should be added to the journey time and how to store the fare used.

The first question that should be asked by the modeller is 'how fares are actually perceived?' There is no point in having a complicated procedure to calculate fares if they do not really effect the routes taken. Many types of fares do not affect the route chosen and may be effectively ignored. Once fares are included in a model there does appear to be a tendency to increasing complexity which might not always be justified by the results obtained.

4. Types of Fare

Before considering how fares may be modelled in Emme/2 it may be helpful to briefly review the main different types of fares and how they can affect passenger behaviour.

Time-based Tickets

On many public transport systems people mainly use time-based tickets, such as season tickets or passes, available on all modes. In this case the routes and services chosen are unaffected by the fare paid as the fare is 'free' for a each additional boarding and the passenger can chose the 'quickest' way (taking into account of course the deterrence effect of walking, waiting and interchange). In this situation there is little point modelling fares. Even when there is a different fare system for non regular journeys as is common in the UK, the predominance of season tickets for peak journeys, particularly for those journeys where an interchange is required, may mean that the impact of fares on passenger choice can be effectively ignored. This is often a convenient assumption to avoid having to model fares.

Single tickets which allow free transfer throughout the system within a specified time period are rare in the UK but common elsewhere. This type of ticket also does not affect routeing through the network and means that fare modelling can be ignored.

In these situations revenues can be calculated directly from the number of trips (not boarders), taking into account any differences in the fares paid by different groups of users (for example children and elderly users).

Zonal Fares

Zonal based fares usually depend on the ultimate origin and destination point rather than the route so again fares do not affect the choice of route or services - people simply use the quickest route between two points. Therefore the effect is generally similar to that of time-based tickets. An exception is where the pattern of zones leads to a higher fare for some routeings, for example those passing though the Centre Area. This may then affect the route taken and hence the choice of service used. In the UK zonal fares are sometimes used for season tickets but rarely for single tickets.

Flat Fares

Flat fares, where a standard fare is paid on boarding a vehicle, are like season tickets if free transfer is allowed . Where this is not the case the flat fare effectively acts as a boarding penalty which further discourages interchange. It is normal in public transport modelling to include a boarding penalty to represent the inconvenience of changing vehicles. This is in addition to actual walking and waiting time and is typically set at about 5 minutes in urban systems. In principle the flat fare becomes a monetary addition to the boarding penalty as the fare is an additional deterrent to changing vehicles. Flat fares are used on some services in the UK but not across entire systems because most operators have to attempt to maximise revenues and flat fares usually require heavy revenue support.

Distance-Related Fares

On some (mainly rail) systems fares are directly related to distance. In this case the fare may affect the general choice of route in favour of more direct services even if these are slower. If the fare rate differs between services it is usually a trade-off between speed and cost. In terms of modelling, the effect of including a fare is to effectively 'slow' all services down as the generalised cost of travel increases. For example consider the situation of a typical rail fare of £0.10/km and a value of time of £0.04 per minute. This fare rate represents 2.5 'fare-minutes' per km. For a rail service at a speed of 100km/h the actual journey time is 0.6 minutes per km so the inclusion of a 'fare-time' greatly increases journey time. For a 100km journey this increases from 60 minutes to 310 minutes! A decision to include fares in the journey time is therefore a critical one. This also explains why fares are regarded as so important to the competitiveness of inter-urban rail services. The effect is less for urban journeys where bus times of 3 to 4 minutes per km are more typical so the fare is proportionately less even though the rate per mile may be higher..

Of course these effects are only relevant if fares vary considerably between different services. Clearly as competition within the travel market grows this will become increasingly the case particularly for longer distance journeys.

Distance-related Fares with Boarding Penalty

Other fares effectively consist of a fixed boarding penalty plus a distance related element - a combination of the two types of fares discussed above. The effects are also a combination - interchange is discouraged by the boarding penalty and the distance based fare may determine routeing or choice of service.

Stage Based Fares

A fare system in common use in the UK is 'stage' fares where fares relate to the number of stages passed. These are usually defined by some of the stops along the route, stages usually being related to distance. However this type of fare is different to distance-related fares in two important ways:

- fares are not linear and are usually strongly tapered for longer distances; and
- no interchange between vehicles is allowed.

Table 1 below illustrates a typical stage fare structure used by a bus operator in the UK.

TABLE 1 TYPICAL STAGE FARE SYSTEM

Stages (km)	Fare (pence)	Fare p/km	Fare p/km with

	£1=100p		assumed 10p boarding penalty
1	30	30	20
2	50	25	20
3	65	22	15
4-8	90	23-11	10-20
9-13	120	13-9	8-12
14+	140	10 and falling	9

The fare/km for short journeys is very high but tapers markedly for longer journeys, partly reflecting the characteristics of the UK bus market, where most journeys are short and the main source of revenue, and longer journeys may be more optional particularly at off peak times. There is also no doubt a desire to reduce the number of fares that staff and passengers have to remember. This particular scale has a flat fare off peak for all journeys greater than 4km. The initial fare can almost be regarded as a boarding penalty (see last column) which significantly reduces the variation in the marginal rate per km which becomes more linear, at least at short distances.

The main impact of this type of fare system is to discourage interchange. Consider a typical 8 km journey. The fare paid depends on both if an interchange takes places and also *where* it takes place as shown in Table 2.

TABLE 2 IMPACT OF INTERCHANGE POINT ON FARES PAID

Km travelled before interchange	Fare paid
no interchange	90
1 km	120
2km	140
3km	155
4km	180

The penalty for interchange ranges from 30p to an amazing 90p if the interchange takes place at the 'wrong' place.

This type of fare structure, particularly if different for different operators is a modellers nightmare!
However, many operators do provide day passes which provide an alternative for people, particularly if they are making return journeys. In this case the day pass is 240p so becomes the sensible option for most return journeys involving interchange over about 5km. Compared with a through journey the effective interchange penalty is about 30p although this becomes smaller for longer journeys. A reasonable compromise may be to use an average penalty which represents that encountered on the average journey.

5. Application of Fares within the Emme/2 Assignment Process

There are no fare variables or tables in Emme/2 but fares can be modelled using the normal data items found within Emme/2. This has some advantages of flexibility but also severe limitations.

The starting point for the modeller is to review the main fare systems in operation and how these will affect the assignment. If there a different fare systems used by different groups of people (for example those using season tickets and those using single tickets) and there is sufficient information available, consideration could be given to splitting the matrix and assigning partial matrices based on different fare parameters.

Use of Boarding Penalty

If the main impact of the fare system is to discourage interchange the simplest way to model this is to use a boarding penalty, converted to time and added to any standard penalty already in place to discourage interchange. In Emme/2 this may be system wide, related to a node, or a transit line. In most cases the former will be most appropriate or the latter where fares vary by service. This method applies to flat fares with no interchange allowed and where fares are distance based with a boarding penalty. However as discussed above this may also be used as a crude proxy for other fare structures which discourage interchange.

Use of Transit Time Functions

For most fares the most obvious approach is to incorporate the fare in the journey time using the travel time functions. It is worth recalling the keywords which can be referenced in these functions:

length, speed, timau, ul1..ul3, us1..us3, ut1...ut3, veh

Clearly fares can be related directly to distance by applying *length*fare/vot* where vot is cost/minute in the same units. It is also possible to put a marker on a link to represent a fare change point (which is then multiped by a particular fare increment) or an actual fare which is incurred by people passing that point (in effect a toll for using that link). The options available using the user data items can make this specific to a network link (ul), a link used by a particular line (us) or, less usefully, all links, but with a value specific to a particular line (ut).

However fares (as are journey times) are calculated on a link by link basis (or more strictly segment by segment) so it is not possible to derive a fare based on the characteristics of the total journey on a particular public transport service. For example if distance is used to calculate fare the total fare must be directly related to the distance, there cannot be a taper.

Fares specifically put on links can be used to model irregular fares but only if the fare change is constant at a particular point. This may be the case with zonal systems where the fare increases when crossing a specific boundary, but even for these systems the number of zones crossed is rarely directly related to the fare paid so again there is effectively a fare taper..

From a single point on a service it may be possible replicate a tapered fare using the user data items as shown in Table 3.

TABLE 3 APPROXIMATION OF STAGE FARES

Link (assume l km links)	Fare on Link	Fare from Start
1	30	30
2	20	50
3	15	65
4	35	90
5	0	90
6	0	90
7	0	90
8	0	90
9	30	120
10	0	0

However the limitations of this approach soon become obvious as intermediate trips would incur very erratic fares. For example someone boarding at the start of link 5 could travel to the end of link 8 without incurring a fare!

Therefore this approach could only be used in special circumstances such as modelling the choice between two services having different fares from a single destination to a number of different destinations. However if interchange is an issue the above approach clearly would not work and a hefty interchange penalty would be required to prevent interchange between the services.

Conclusion

It is possible to model simple fares using the facilities within Emme/2 but more complex systems have to approximated. Whether or not this is possible depends crucially on what effect is trying to be modelled. This requires careful thought and takes time which is a major disadvantage compared with being able to directly code fare structures in the model.

6. Calculation of Fares for Input to a Mode Choice Model

If fares are a major influence on route choice it is likely that other factors such as service quality are also important in consumer choice and it becomes less likely that the assignment process would adequately reflect the choice process. In this case it might be better to apply a matrix-based mode choice model using Emme/2 to derive costs by the alternative modes using a selective assignment. In this case it is possible to use the 'additional options' assignment to store information (such as total distance or fare stages passed) which can then be used to calculate a fare for input into the mode choice model. This means that fares need no longer be linear as (using the above example) each origin-destination pair passing 8 stages could be allocated a fare of 90p. However if an interchange has occurred this will be too low for the reasons described above. Using the earlier example the fare could vary between 120 and 180 (see Table 2). The number of interchanges is known from the assignment which would allow some adjustment to be made but it will still be an approximation because the point of interchange is not known. An alternative is to use the network calculator to 'manually' set up a fares matrix, possibly taking into account the number of interchanges.

7. Calculation of Revenues

Assuming total origin to destination fares can be approximated as a matrix, either using the assignment or manual methods, the calculation of total revenues is a simple matrix calculation. Calculation by individual service is a greater problem. If fares are related to number of boardings and/or passenger-km it is also a simple network calculation to calculate revenues for each service. More complex calculations can be undertaken using the network calculator and the additional options assignment process. However It should be noted that including fares in the transit time functions effects the outputs in the results modules so obtaining simple information on passenger hours becomes a more complex process.

8. Emme/2 Fares for the Future?

It is the authors view that the lack of explicit fares modelling in Emme/2 detracts from the usefulness of Emme/2 for public transport. There follows some initial thoughts on what may be required.

It would be useful as a start if a fare item, either an actual fare or a fare stage, could be added to a segment and optionally included in the transit time calculation insofar as it affects the assignment but saved in a separate matrix to the in-vehicle time. However what is really required is a means of accumulating the number of fare stages (or points where the fare changes) passed since the initial boarding up to the current stop and then the use of a look-up table to calculate the correct fare to that point to add to the in-vehicle time to that point. The fare then need to be stored in a matrix in a similar way to that used for the in-vehicle time. The fare structure itself could be stored as a type of function selected on the basis of some data included in the transit line. Typical fare forms could be:

- boarding fare plus fare per km
- boarding fare plus fare for 1 stage since boarding, 2 fares since boarding etc.

This would give the flexibility to model most types of fares and store the revenues emerging from the assignment process.

Although there are no doubt technical problems to implementing this type of solution it is hoped that some improvements will be possible in future releases of Emme/2.

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